USAID ALTERNATIVES TO CHARCOAL

COST OF COOKING STUDY

FULL REPORT

February 2023

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EXECUTIVE SUMMARY

Zambia's deforestation rate is among the highest in the world, with an estimated 200,000 hectares cleared annually. The use of charcoal is a primary driver of deforestation and forest degradation in Zambia due to its dominant role in household cooking across all income levels. The goal of the USAID/Zambia Alternatives to Charcoal (A2C) project is to reduce charcoal energy consumption in urban and peri-urban areas of Zambia (inclusive of Lusaka) and catalyze an increase in the use of low emission charcoal alternative technologies and/or fuels. A2C will achieve these goals by ensuring that alternative technologies and fuels are accessible, affordable, and culturally acceptable.

The objective of this Cost of Cooking study is to better understand the cost competitiveness of various alternative technologies and fuels compared to charcoal and each other. This was assessed through a series of Controlled Cooking Tests (CCTs) on a set of standard Zambian dishes, conducted by typical Zambian cooks. A2C conducted the CCTs on **eight cooking technologies and fuels**. The tests were carried out by **three cooks**. Each cook prepared all **seven dishes**, on each of the cooking technologies, **once**. The controlled cooking test (CCT) is designed to assess the performance of an improved stove relative to the common or traditional stoves that the improved model is meant to replace. Stoves are compared as they perform a standard cooking task that is close to the actual cooking that users do every day. However, the tests are designed in a way that minimizes the influence of other factors and allows for the test conditions to be reproduced.

The seven dishes were selected to represent the most common foods typically cooked for breakfast, lunch, and dinner. These included: maize meal porridge (breakfast), nshima, kapenta stew, rape vegetables (lunch), plain white rice, beef stew and bean stew (dinner). A set recipe was developed for each dish based on feeding an average family of five people. All seven dishes were combined into a "daily cost" of cooking and then scaled using adjustment factors to estimate a monthly cost of cooking. However, the monthly cost of cooking is still likely to be an overestimate as households are unlikely to cook all seven dishes in a day and highly unlikely to cook them as frequently over the course of a month as we have estimated. The dishes were cooked on four electric appliances (EPC, hotplate, two models of induction cookers), an LPG stove, an ethanol stove, a gasifier stove (with pellet fuel) and the traditional charcoal mbaula.

In recognition that all fuels have a variety of prices, some of which with large ranges, this study uses three fuel price points: Low, Medium, and High. For electricity, we used the three residential tariff bands (R1, R2, R3). For pellets we used the price per kilogram for the three different bag sizes (5Kg, 20Kg, 50Kg). While for charcoal we used the cheapest and most expensive price per kilogram for the sixteen bag sizes A2C tracks on a monthly basis. The medium charcoal price was taken from the most commonly purchased bag type (25Kg 1 Ball Pen). Similarly, for LPG we used the cheapest and most expensive price per Kg from all the suppliers, and cylinder sizes, the project tracks on a monthly basis. The medium LPG price was taken from the most widely available cylinder size (6 Kg). For all the fuels, the medium price point represents where most consumers fall.

The study first assesses the cost of cooking based on **fuel consumption only**, using the most recent fuel price data for each of the cooking solutions. We then determine a **cost per meal for the appliances** based on the cost of the appliance and its operational lifetime. Finally, the cost of cooking with the fuel is combined with the cost of cooking with the appliance to determine and **overall cost of cooking metric**. The combined figure is used to determine potential savings of switching from charcoal, as well as assess the most suitable clean cooking stacks which meet a household's affordability, accessibility, and acceptability requirements. The report also explores the impacts of fuel price variations on the cost of cooking and how this changes the relative competitiveness of each cooking solution. Finally, we explore how the behavior of the cooks impacts the performance of the stove, and ultimately, the cost of cooking.

Key Takeaways

- Fuel prices can have a significant impact on the relative performance of the cooking solutions. Charcoal and electricity have the widest price ranges of all the fuels. Both increase roughly fourfold between the cheapest and most expensive options. While the price variations for LPG, ethanol and pellets are more modest.
- The cost of the appliance, when spread across its operational lifetime, is a minor contributor to the overall cost of cooking (results summarized here include both the fuel and the stove). However, without consumer finance, the upfront cost of the appliance is likely to remain a barrier.
- At the low and medium tariffs electricity is currently the most cost-effective fuel, and cooking with an EPC is the most cost-effective appliance. Even at the highest tariff an EPC is the cheapest cooking option.
- Hotplates were the second cheapest cooking option, suggesting more focus should be placed on the role they can play in reducing charcoal consumption in grid-connected households.
- Using a gasifier stove with pellets is cheaper than charcoal at the medium and high charcoal price points but using the lowest charcoal price makes cooking on charcoal slightly cheaper than pellets.
- Liquid fuels (ethanol and LPG) are the most expensive cooking fuels. However, compared with the highest charcoal price, LPG can be cost competitive. This suggests that PAYGo LPG, targeted at lower income charcoal consumers, could be an attractive offer.
- Cooking bean stew has a major impact on the cost of cooking. Removing beans from the analysis makes LPG cost competitive with charcoal at the medium fuel price points. Removing beans also makes the induction cookers perform the same as the hotplate.
- Performance of the appliances, with the exception of EPCs, seems to depend heavily on the behavior of the cooks. Cooks tend to use as much power as is available to them, which impacts fuel consumption and ultimately the cost of cooking. Including pre-programmed dish settings could be an important strategy to ensure efficiency gains are realized in households.
- The most effective clean cooking stack based on affordability, accessibility, and acceptability is the EPC with the Gasifier stove. This stack allows households to cook all dishes (acceptability) at a lower cost than charcoal (affordability) and ensures they are not impacted if there are shortages with either of the fuels (accessibility)
- Projections of future price increases up to December 2025 suggest that electricity and pellets will remain cheaper than cooking on charcoal. LPG will remain more expensive than charcoal, while securing excise duty waivers on ethanol could make it less expensive than LPG.

1 INTRODUCTION TO STUDY

Zambia's deforestation rate is among the highest in the world, with an estimated 200,000 hectares cleared annually. The use of charcoal is a primary driver of deforestation and forest degradation in Zambia due to its dominant role in household cooking across all income levels. The goal of the USAID/Zambia Alternatives to Charcoal (A2C) project is to reduce charcoal energy consumption in urban and peri-urban areas of Zambia (inclusive of Lusaka) and catalyze an increase in the use of low emission charcoal alternative technologies and/or fuels. By reducing charcoal consumption and increasing the use of alternatives A2C aims to reduce deforestation directly attributable to charcoal production.

A2C will achieve these goals by ensuring that alternative technologies and fuels are accessible, affordable, and culturally acceptable. While the range of cooking fuels and technologies available to urban Zambian consumers has steadily grown and diversified over the years, the popularity and preference of using charcoal for cooking in a traditional burner, commonly referred to as the 'mbaula', persists.

A range of alternative technologies and fuels (ATFs) to charcoal do exist in Zambia, including stoves powered by electricity and/or solar, liquid petroleum gas, processed biomass (e.g., pellets), and ethanol gel fuel. However, the widespread adoption of each of these technologies in Zambia is currently hindered by poor enabling conditions and market barriers that keep costs prohibitively high and limit access, while specific social and cultural barriers for different consumer segments limit their cultural acceptability as an alternative to charcoal. These challenges must be addressed if ATFs are to replace charcoal as the low-cost household energy of choice in Zambia.

The objective of this Cost of Cooking study is to better understand the cost competitiveness of various alternative technologies and fuels compared to charcoal and each other. Understanding this dynamic will be critical to providing support to companies in the sector, and for them to better understand their product-market fit. In turn, this can help inform social behavior change communication material aimed at transitioning consumers away from charcoal to modern alternatives. In addition, understanding the cost to households will form an evidence base for informing national policies and strategies, such as a National Clean Cooking Strategy and Action Plan. This study uses a series of Controlled Cooking Tests (CCTs) on a set of standard Zambian dishes, conducted by three typical Zambian cooks. The study assesses both the cost of the fuel, and the appliance, on a daily and monthly basis.

A2C conducted the CCTs on **eight cooking technologies and fuels** covering: two induction cookers (ATEC and Platinum), an electric hotplate, an EPC, a liquid ethanol stove, an LPG stove, a gasifier stove (with pellet fuel) and a traditional charcoal mbaula. The tests were carried out by **three cooks**, each coom prepared all **seven dishes**, on each of the cooking technologies, **once** for a total of 168 dishes cooked. The study aims to understand:

- The cheapest and most expensive cooking solutions
- The relative importance of the stove cost compared to the fuel cost
- The savings a household can make by switching between different stoves and fuels
- The extent to which cooking practices change the cost of cooking with different stoves and fuels
- The most effective clean cooking stack based on affordability, accessibility, and acceptability
- The impact that fuel price variations have on the relative cost competitiveness of the ATFs
- The cooking times required for each dish on each technology, as well as time savings from switching.

2 DISH AND MEAL SELECTION

To identify the most representative set of Zambian dishes to be included in this study A2C completed a review of relevant literature from the FCDO funded MECS program. This review included the MECS Cooking Diaries Report (2019), the Zambian eCookbook, and the recent results of the 2021 cooking diary activities. Based on this review, the most common dishes were selected, and a set of standard recipes prepared. The recipes were created in collaboration with the expertise of a Zambian Kitchen chef (Precious Phiri). All seven dishes combined represent the **"daily menu"** and the **"daily cost"** of cooking. The menu is summarized in the table below, while the recipes are detailed in the following sections. All recipes are based on feeding a family of 5 people.

Table 1: Summary of Dishes and Meals

Meal	Dish(es)
Breakfast	Maize meal porridge
Lunch	Nshima
	Kapenta stew
	Rape vegetable
Dinner	Plain white Rice
	Meat (beef stew)
	Bean Stew

To estimate a **<u>monthly cost</u>** of cooking A2C applied conversion factors to scale the daily menu (Table 1) to a more realistic monthly estimate. These conversion factors recognize that (1) households do not always cook every meal each day and (2) not all meals are cooked fresh, but some are likely to be re-heated and therefore require less fuel (this is particularly true for a dish such as beans). Data used to determine monthly conversion factors was taken from the MECS eCook Zambia Cooking Diaries working paper (2019).

Based on this data, it is estimated that breakfasts are prepared 54% of the time (16 days per month), lunches are prepared 62% of the time (19 days per month) and dinners are prepared 80% of the time (24 days per month). In addition to this, not all meals are prepared from scratch, as some are <u>partially</u> cooked (meaning some of the dishes are re-heated and some dishes are cooked from scratch). The MECS report indicates that 7% of breakfasts, 15% of lunches and 27% of dinners are partially cooked. Energy required for partially cooking breakfasts is 57%, lunches 92% and dinners 79% of the amount used to prepare a dish from fresh.

While our adjusted monthly figures provide an estimate which is closer to reality, it's likely they still overestimate the cost of cooking due to the beans dish which typically accounts for 24% - 58% of the cost of cooking and is unlikely to be prepared freshly as frequently as our analysis assumes. This is supported by the MECS finding that beans are re-heated approximately 44% of the time. Making additional adjustments for this would decrease the monthly cost estimate further.

2.1 NSHIMA RECIPE

Ingredients:

- 3 liters of water
- 900g breakfast mealie meal/corn meal

Directions

- STEP 1: Add 3 liters of water into a pot and cover with a lid. Heat the water until it starts to boil with small bubbles forming.
- Note: the time taken to reach the required warm temperature varies from one cooking device/fuel to another
- STEP 2: When the water is warm, slowly add in 300g of the mealie meal while stirring continuously to avoid the formation of lumps in the mixture
- STEP 3: Stir until a thick porridge is formed and it starts to bubble
- STEP 4: Close the lid halfway and let it cook while bubbling vigorously for approximately15 minutes
- STEP 5: Start adding mealie meal slowly while stirring to avoid the formation of lumps; add all the remaining 600g of mealie meal until the mixture is well combined. The resulting mixture stops bubbling and has a smooth finish.
- STEP 6: Cover with a lid and let it rest on the heat for 2-3 minutes, open and stir again; the nshima is now ready to serve

2.2 RAPE VEGETABLES RECIPE

Ingredients:

- 600g rape vegetables
- 1 small tomato, diced (90g)
- 1 small onion, chopped (50g)
- 3 tablespoons cooking oil
- 1 teaspoon salt

Directions

- STEP 1: Wash and cut the vegetables thinly
- STEP 2: Add 3 tablespoons of cooking oil into the pot and let it heat for about a minute
- STEP 3: When its heated, add the tomatoes, onions and 1 teaspoon of salt
- STEP 4: Stir to make gravy
- STEP 5: Add the rape vegetables and stir for 8 minutes
- STEP 6: When the rape vegetables become cooked, they are soft and retain a vibrant, green color; the vegetables are ready to serve.

2.3 PLAIN WHITE RICE RECIPE

Ingredients:

- 1200g plain white rice
- 1200mls water
- 2 tablespoons cooking oil
- ¼ teaspoon salt

Directions

- STEP 1: Remove the dirt particles from the rice and rinse it in water
- STEP 2: Add 1 liter of water in a pot
- STEP 3: Add 2 tablespoons of cooking oil and ¼ teaspoon salt
- STEP 4: Add the rice, cover with lid halfway and let it boil for 20 minutes
- STEP 5: Once the water dries up, check if the rice is no longer crunchy, if it still is, add a bit more water, about 200mls and let it simmer
- STEP 6: Take off the lid and check if the rice is now tender, the rice grains compress into a paste when softly pressed between thumb and finger
- STEP 7: Let it sit for 2 minutes with an open lid to allow excess moisture to dry off; the rice is now ready to serve

2.4 KAPENTA STEW RECIPE

Ingredients:

- 140g Dry kapenta
- 1 medium sized tomato, diced (130g)
- 1 medium sized onion, chopped (70g)
- 5 tablespoons cooking oil
- 1 teaspoon salt

Directions:

- STEP 1: Remove the unwanted particles from the kapenta
- STEP 2: Rinse kapenta in lukewarm water
- STEP 3: Add 5 tablespoons of cooking oil in a pan and when hot add the kapenta, 1 teaspoon salt and stir continuously
- STEP 4: Continue stirring until the kapenta becomes crunchy and brownish
- STEP 5: Add the onions and tomatoes and continue stirring for approximately 7 minutes; the dish is now ready to serve

2.5 BEEF STEW RECIPE

Ingredients:

- 1 kg beef stewing meet
- 1 medium sized tomato, diced (130g)
- 1 large onion, chopped (70g)
- 2 teaspoons salt
- 4 tablespoons cooking oil
- Water

Directions

- STEP 1: Cut the beef into pieces (about 5x5x5 cm cubes) and rinse it in clean water
- STEP 2: Place beef into a pot with 100mls of water (200mls for EPC), 2 teaspoons salt and 1 tablespoon of cooking oil
- STEP 3: Let it boil for at least 1 hour (set P01 for EPC), adding more water (100mls) every time it dries up (except for EPC) until the meat is tender.
- STEP 4: Drain the water from the beef before you add cooking oil when preparing in the EPC. Let the water dry up for the other stove top devices
- STEP 5: Add 3 tablespoons of cooking oil and fry the beef in the pot
- STEP 6: When it is brown, add some onions and stir until they are caramelized.
- STEP 7: Then add some tomatoes and stir until they are cooked (tomatoes should be easily mashed with a spoon).
- STEP 8: Add a bit of water, 100mls and let it simmer for 10 minutes to form thick gravy; when gravy is thick its ready to serve

2.6 BEAN STEW

Ingredients:

- 500g dry Beans
- 2 Medium tomatoes, diced (130g)
- 1 Medium Onion, chopped (70g)
- 3 Tablespoons cooking oil
- 1 ½ teaspoon salt
- Water

Directions:

- STEP 1: Sort your beans, removing the unwanted particles
- STEP 2: Wash, drain and place in the pot.
- STEP 3: Add 1500mls of water and 3 tablespoons of cooking oil

- STEP 4: Boil the beans adding more water every time it dries up (200mls per time) until it is tender but firm. Periodically try a taste test or mash a bean against the side of the pot with a fork or spoon.
- STEP 5: Add in the tomatoes, onions, and salt.
- STEP 6: Add 200mls of water and cover the pot and let the beans simmer
- STEP 7: When the beans can easily be mashed with little pressure from a spoon or fork, it is now ready to serve.

2.7 MAIZE MEAL PORRIDGE

Ingredients:

- 3 liters water
- 400g breakfast mealie meal
- 6 tablespoons of sugar
- ½ teaspoon salt
- 2 tablespoon cooking oil

Directions:

- STEP 1: Add 3 liters of water into a pot and cover it with a lid. Heat the water until it starts boiling with small bubbles forming.
- STEP 2: When the water is warm, slowly add in the 400g of the mealie meal while stirring continuously to avoid the formation of lumps in the mixture
- STEP 3: Stir until a thick paste is formed and it starts to bubble
- STEP 4: Cover the pot and let it cook for about 5 minutes while stirring from time to time
- STEP 5: Add in 6 tablespoons of sugar, 2 tablespoons cooking oil, ½ salt and stir
- STEP 6: Cover again and let it cook. The mixture should begin to come away from the pot but should not be brown or burnt; the dish is now ready to serve

3 METHODOLOGY

Through this study A2C set out to understand the affordability of various cooking fuels and technologies and to answer the following key questions:

- What are the cheapest and most expensive cooking solutions?
- What is the relative importance of the stove cost compared to the fuel cost?
- What savings would a household make by switching to different stoves and fuels?
- To what extent do cooking practices change the cost of cooking?
- What is the best clean cooking stack based on affordability, accessibility, and acceptability?
- How much do fuel price variations impact the cost competitiveness of the cooking solutions?
- How much time could households save by switching from charcoal to modern alternatives?

Typically, there are three main stove performance testing standards, the Water Boiling Test (WBT), the Controlled Cooking Test (CCT) and the Kitchen Performance Test (KPT) which are summarized in the table below. For this study we chose to apply the Controlled Cooking Test protocol. CCTs were chosen as they are conducted on typical national dishes, by local household cooks, and allow for detailed fuel consumption data to be collected at the dish level. CCTs also capture the impact of cooking behavior which is crucial for understanding the true cost of cooking once a user gets the appliance into their home. Water Boiling Tests (WBTs) were deemed unsuitable as they often do not translate well to real world cooking experiences and tend to underestimate the benefits of modern appliances (control, insulation, pressurization). While Kitchen Performance Tests (KPTs) lack the granularity required at the dish level to determine, and compare, the costs of cooking. Furthermore, it is often difficult to understand how much fuel stacking is happening in a household through KPTs.

<table>
<tr><td colspan="2">Water Boiling Test (WBT): A laboratory test that evaluates stove performance while completing a standard task in a controlled environment to investigate the heat transfer and combustion efficiency of the stove. They reveal the technical performance of the stove only under the conditions of the WBT, and not necessarily under real cooking conditions. They are conducted by trained technicians, rather than local cooks, and therefore can't provide insight into how the stove performs when cooking under realistic conditions.</td></tr>
<tr><td>Strengths: Simplicity, replicability, speed, and low cost to conduct. They can provide preliminary understanding of stove performance and therefore help to inform the stove design process.</td><td>Weaknesses: Only provides a rough approximation of actual cooking. Studies have shown that WBTs are not good predictors of actual fuel use when compared to measurements of fuel use in households.</td></tr>
<tr><td colspan="2">Controlled Cooking Test (CCTs): A laboratory, or field, test that measures stove performance in a controlled setting using a standard task chosen to emulate local practices. They reveal what is possible in households but not necessarily what is actually achieved by a household in daily use. They should be conducted by a person who is familiar with the meal, the traditional stove, and the modern stove.</td></tr>
<tr><td>Strengths: Relative simplicity, replicability, speed, and low cost to conduct. They can provide understanding of stove performance for local cooking at a dish and meal level.</td><td>Weaknesses: Controlled conditions (including fuel, food, procurement, and training) still do not reflect totally uncontrolled usage which is sensitive to differences in operator behavior.</td></tr>
</table>

Kitchen Performance Test (KPT): A field test used to evaluate stove performance in real-world settings. It is used in the homes of stove users and is designed to assess actual impacts on household fuel consumption. Typically, they are carried out firstly on the baseline stove (e.g., traditional mbaula) to understand how much fuel is being consumed and then in the same household on the new, intervention stove (e.g. improved charcoal cookstove) to see how much fuel is being consumed. For this reason, they are less appropriate when comparing between stoves that use different fuel types. Tests are often conducted over several days and record how much fuel is used in each 24-hour period to arrive at an average daily fuel consumption per household per day.

Strengths: Allows for the best understanding of daily fuel consumption and general household behavior with regards to the stoves.

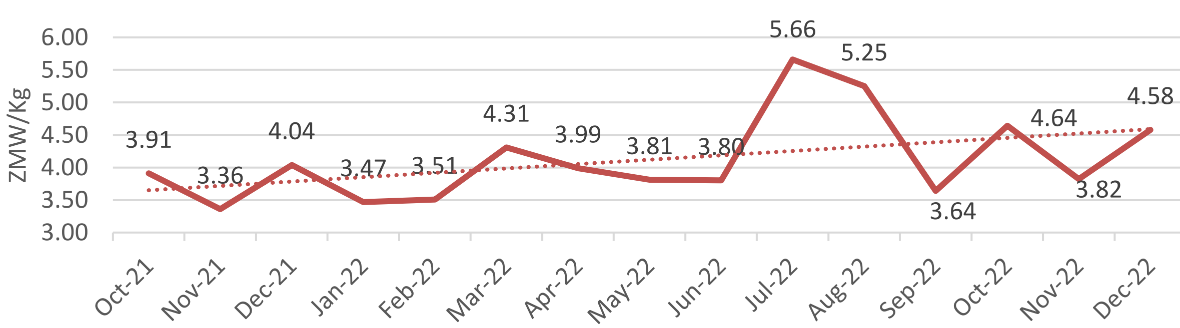
Weaknesses: Labor intensive, more variability in results due to less controlled testing situation, more sensitive to survey/study design. Hard to understand the extent of fuel stacking happening in a household. Difficult to understand fuel consumption per dish.

3.1 TECHNOLOGIES AND FUELS

A2C selected five fuels (electricity, LPG, pellets, ethanol, and charcoal) and seven technologies (EPC, hotplate, platinum induction cooker, ATEC induction cooker, gasifier stove, LPG stove, and the charcoal Mbaula) to conduct testing on. These technologies and fuels represent the primary cooking solutions available to urban households in Zambia.

As part of A2Cs monthly context monitoring the project collects data on charcoal prices. Four charcoal markets in Lusaka are visited (Mandevu, Kanyama, Chawama, and Mtendere). Data is collected for 16 different bag sizes, which were identified during the projects Baseline data collection in November 2021. The weights of each of the 16 different bag sizes were measured, allowing us to determine an average price per kilogram of charcoal across all bag sizes and markets, as shown in the graph below. Since data collection started in October 2021 the average price per kilogram of charcoal has fluctuated from 3.36 ZMW/kg to 5.66 ZMW/Kg. These fluctuations represent changing supply-demand dynamics due to seasonality of charcoal production and consumption. However, the general trend illustrates a gradual increase in charcoal prices over time.

Figure 1: Average Charcoal Price Over Time



For the purposes of this study A2C used charcoal pricing data from December 2022 as shown in Table 2 below. The price varied widely from a low of 2.4 ZMW/kg up to a high of 8.8 ZMW/kg depending on the bag size purchased, with prices typically decreasing as bag sizes increase. According to the A2C Baseline

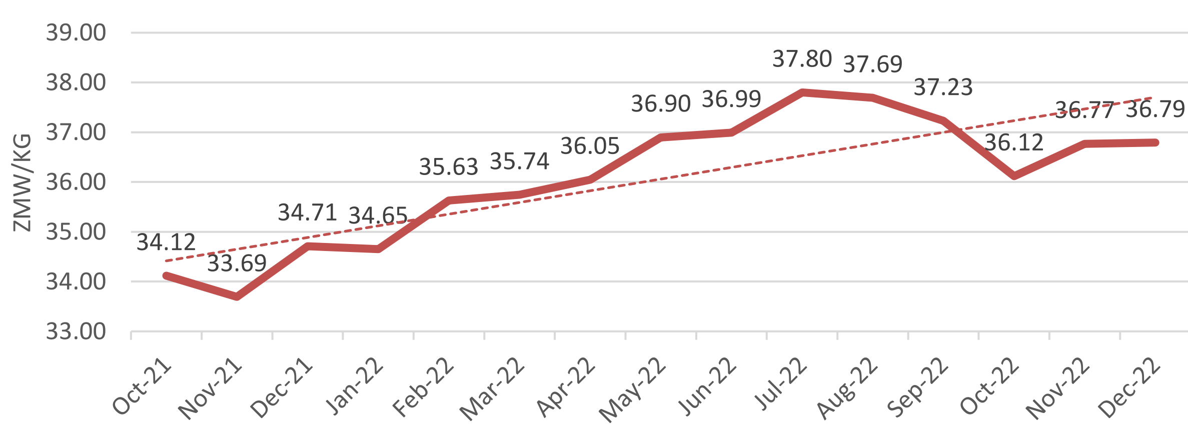
Study (Nov 2021) the most commonly purchased bag size is the "25 Kg 1 Ball Pen Head" which is bought by 37% of charcoal users, with an average charcoal price of 5.5 ZMW/kg.

Table 2: Charcoal Prices by Bag Size (December 2022)

Bag Size/Type	% HHs Purchasing	Ave. Price (ZMW)	Ave. Weight (Kg)	Price/Kg
90 kg green label 2 ball pen head	3%	288	122.3	2.4
90 kg green label no head	2%	213	82.4	2.6
90 kg green label 3 ball pen head	5%	376	144.4	2.6
50 kg 1 ball pen head	5%	122	42.6	2.9
50 kg no head	3%	111	38.4	2.9
50 kg 3 ball pen head	7%	253	78.9	3.2
50 kg 2 ball pen head	8%	186	57.7	3.2
90 kg green label 1 ball pen head	2%	240	71.7	3.3
25 kg no head	7%	86	23.2	3.7
1 kg smallest plastic bag	4%	2	0.4	4.9
10 kg half ball pen	2%	60	11.9	5.0
25 kg 1 ball pen head	37%	110	20.0	5.5
3 kg plastic bag	3%	8	1.3	6.3
2 kg plastic bag	7%	6	0.8	7.4
5 kg large plastic bag	3%	24	3.0	7.9
4 kg plastic bag	2%	13	1.5	8.8
			December Average	**4.5**

Similarly, A2C collects monthly price data on LPG across different LPG suppliers and a range of cylinder sizes to determine an average price per kilogram for Lusaka. A total of nine LPG suppliers are visited (Afrox, Oryx, Mt. Meru, Ogaz, Lake Petroleum, Falcon Gas, Rubis, CADAC and Mic Mar) covering 14 different cylinder sizes ranging from the refill price per kilogram through to a 48 Kg cylinder. Since data collection began in October 2021 LPG prices have ranged from 33.7 to 37.8 ZMW/kg. However, the trend line indicates a gradual increase in LPG prices over time.

Figure 2: Average LPG Price Over Time



For the purposes of this study A2C used LPG pricing data from December 2022 as shown in Table 3 below. The price in December varied from a low of 33.4 ZMW/kg up to a high of 42.9 ZMW/kg depending on the cylinder size purchased, with prices generally decreasing as cylinder sizes increase. The most commonly available cylinder size is the 6 Kg which was stocked by 89% of suppliers surveyed, with an average LPG price of 36.4 ZMW/kg. This cylinder size is typically used by residential customers, while the larger cylinder sizes are typically used by commercial and industrial customers.

Table 3: LPG Prices by Cylinder Size (December 2022)			
Cylinder Size	**% of Suppliers Stocking**	**Ave Price (ZMW)**	**Price ZMW/Kg**
35 Kg Cylinder	11%	1170	33.4
38 Kg Cylinder	44%	1210	34.8
12 Kg Cylinder	11%	420	35.0
15 Kg Cylinder	33%	533	35.6
48 Kg Cylinder	22%	1712	35.7
45 Kg Cylinder	22%	1638	36.4
6 Kg Cylinder	89%	219	36.4
19 Kg Cylinder	33%	700	36.9
9 Kg Cylinder	33%	335	37.2
14 Kg Cylinder	22%	526	37.6
Per Kg Refill	56%	37	37.6
5 Kg Cylinder	22%	193	38.5
3 Kg Cylinder	22%	116	38.7
7 Kg Cylinder	11%	300	42.9
		December Average	**36.9**

Pellet fuel can be purchased in three different bag sizes with pellet prices ranging from a low of 3 ZMW/Kg to a high of 4.8 ZMW/Kg. The most commonly purchased bag size is the 20Kg, which represents 85% of all pellet sales.

Table 4: Pellet Prices by Bag Size (December 2022)			
Fuel	**Quantity**	**Price/Unit**	**% Of Sales**
Pellets	50 Kgs	3 ZWM/Kg	9%
	20 Kgs	3.5 ZWM/Kg	85%
	5 Kgs	4.8 ZWM/Kg	6%

The price per kilowatt of electricity increases depending on the amount used over the course of a month, ranging from 0.56 ZMW/kWh to 2.31 ZMW/kWh. According to the A2C Baseline Study, 60% of households that practice electric cooking fall within the R2 tariff band priced at 1.01 ZMW/kWh. These households spend between ZMW 60 - 250 a month on their total household electricity bill (including cooking), with an average monthly spend of ZMW 161, equating to 204 kWhs of electricity.

Table 5: Electricity Prices by Tariff Band (December 2022)			
Fuel	**Quantity**	**Price/Unit**	**% Households**
Electricity	R1 Band: <100 kWhs	0.56 ZMW/kWh	4%
	R2 Band: 101 – 300 kWhs	1.01 ZMW/kWh	60%
	R3 Band: >301 kWhs	2.31 ZMW/kWh	37%

Currently the ethanol sector in Zambia is at a very nascent stage with few suppliers of liquid ethanol on the market. For this study A2C procured ethanol from Zhonkai at 65 ZMW / liter.

Table 6: Ethanol Prices			
Fuel	**Quantity**	**Price/Unit**	
Liquid Ethanol	Liter	65 ZMW	N/A

Given the variation in fuel pricing across most clean cooking solutions, this study uses low, medium, and high fuel prices. However, the primary focus of our analysis uses the <u>medium fuel prices</u> as these typically represent where most households fall for a particular fuel. Table 7 below summarizes the low, medium, and high values for each fuel.

Table 7: Summary of Fuel Price Scenarios: Low, Medium, High			
Fuel	**Low Price**	**Medium Price**	**High Price**
LPG (ZMW/Kg)	33.4	36.4	42.9
Charcoal (ZMW/Kg)	2.4	5.5	8.8
Pellets (ZMW/Kg)	3	3.5	4.8
Electricity (ZMW/kWh)	0.56	1.01	2.31
Ethanol (ZMW/Liter)		65	

Cooking appliances were sourced from major suppliers around Lusaka, with the prices presented below. The cheapest appliance on the market was the traditional charcoal mbaula which can be bought for approximately ZMW 20. At the next level up were the Platinum induction stove, the electric hotplate, and the liquid ethanol stove which retail for between ZMW 270 – 550 each. The LPG stove, EPC and gasifier retailed at between ZMW 1000 – 2000, while the ATEC induction cooker is estimated to cost ZMW 2599 when it is launched on the market in Zambia. However, it should be noted that the price of ATEC induction cooker includes a set of three pots/pans, unlike the other appliances.

Platinum Induction		**ZMW 550** **+ ZMW 1200 (pots and pans)**

ATEC Induction (PAYgo enabled)		**ZMW 2599**[1] **(Inclusive of pots/pans)**
LPG Cooker		**ZMW 980**
EPC		**ZMW 1650**
Gasifier		**ZMW 1900**
Liquid Ethanol		**ZMW 270**
Electric Hotplate		**ZMW 315**
Traditional Mbaula		**ZMW 20**

3.2 COOK TRAINING

Three Zambian cooks were recruited (two female and one male). Before the training, the cooks filled in a pre-training assessment which collected information about their cooking history, practices, and experience conducting CCTs. The assessment showed what appliance(s) the cooks had used before, and which ones they would require more detailed training on. During the training session the cooks were trained on: (1) the dishes and recipes, (2) the fuels and technologies, and (3) the testing equipment and data collection forms.

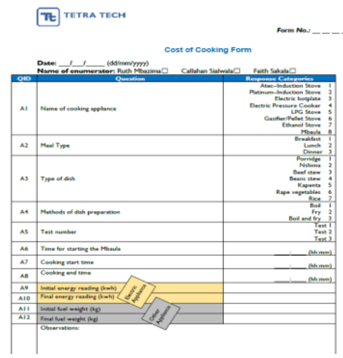
Initially the trainer walked through, and discussed, the recipes, ensuring that cooks understood the expected measurement of ingredients and the procedure to follow when cooking dishes. After the recipes

[1] Product not currently on market in Zambia, so supplier provided an estimated cash-and-carry retail price

and dishes, cooks participated in cooking demonstrations where, each of them practiced cooking a quick dish on each of the appliances. This allowed them to familiarize themselves with how to operate the appliances and the functions they have. Finally, the data from the practice tests was recorded on the data collection forms, allowing the cooks to familiarize themselves on how to collect and record the data accurately.

3.3 TESTING EQUIPMENT AND PROCEDURE

Data collection form: The form used to collect data was designed to be a simple one-page document. The key data collected was the name of appliance, the dish, meal (breakfast, lunch, supper), cooking start and end time, initial and final fuel weight/kWh, and any observations made during cooking. Cooks were not expected to conduct any computations of cooking time or energy used, to avoid manual errors. After cooking was completed, and data verification was done, the data were then entered from the physical form into Kobocollect and uploaded onto the server.


TETRA TECH

Form No.: _ _ _ _

Cost of Cooking Form

Date: ___/___/_____ (dd/mm/yyyy)
Name of enumerator: Ruth Mbazima☐ Callahan Sialwala☐ Faith Sakala☐

QID	Question	Response Categories
A1	Name of cooking appliance	Atec–Induction Stove 1 Platinum–Induction Stove 2 Electric hotplate 3 Electric Pressure Cooker 4 LPG Stove 5 Gasifier/Pellet Stove 6 Ethanol Stove 7 Mbaula 8
A2	Meal Type	Breakfast 1 Lunch 2 Dinner 3
A3	Type of dish	Porridge 1 Nshima 2 Beef stew 3 Beans stew 4 Kapenta 5 Rape vegetables 6 Rice 7
A4	Methods of dish preparation	Boil 1 Fry 2 Boil and fry 3
A5	Test number	Test 1 Test 2 Test 3
A6	Time for starting the Mbaula	___:___ (hh:mm)
A7	Cooking start time	___:___ (hh:mm)
A8	Cooking end time	___:___ (hh:mm)
A9	Initial energy reading (kwh)	
A10	Final energy reading (kwh)	
A11	Initial fuel weight (kg)	
A12	Final fuel weight (kg)	
	Observations:	

Electric Appliance

Other Appliance

Digital Scales: Scales were used to weigh ingredients before cooking, and solid/liquid fuels before and after cooking. To measure ingredients, each of the required ingredients were weighed on its own – placed in a bowl and then on the scale. However, the weight of the bowl was subtracted by first weighing it while empty, tare (or zero) the scale, then add the ingredients. In a similar way, fuels were weighed by placing them on the scale, but there was no need to zero the scale – cooks only ensured they weighed the fuel same way before and after cooking. Therefore, the initial weight of the fuel is larger than the final weight.

Electricity smart meters: The electricity smart meter had two connections, an input and output cable. The input cable with a plug had to be connected to a socket (source of electricity), and when switched on, the current then runs through the meter, to the output cable which had a socket – where the electric stove would be connected to. Before cooking, the connections would have to be completed – meter and stove connected – but the stove will remain off until cooking commences. The smart meter has several power readings, but the 'total power' reading is what was recorded as electricity consumed by the appliance while cooking. The initial reading would be taken before the stove is switched on, and the final reading immediately the stove is turned off – when the dish is cooked. The smart meter records electricity usage in a cumulative format, meaning the initial power recorded will be less than the final power.

4 CONTROLLED COOKING TEST RESULTS

4.1 OVERVIEW OF CCTS

A2C conducted a series of CCTs on **eight cooking technologies and fuels** covering: two induction cookers (ATEC and Platinum), an electric hotplate, an EPC, a liquid ethanol stove, an LPG stove, a gasifier stove (with pellet fuel) and a traditional charcoal mbaula. The tests were carried out by **three cooks**. Each cook prepared each of the **seven dishes**, on each of the cooking technologies, **once** for a total of 168 dishes cooked.

Table 8: Number of Tests Conducted by Cook and Appliance

Technology and Fuel	Cook 1	Cook 2	Cook 3	Grand Total
Atec Induction	7	7	7	**21**
Charcoal Mbaula	7	7	7	**21**
Electric Hotplate	7	7	7	**21**
EPC	7	7	7	**21**
Liquid Ethanol	7	7	7	**21**
LPG	7	7	7	**21**
Local Induction	7	7	7	**21**
Gasifier + pellets	7	7	7	**21**
Grand Total (out of 168)	**56**	**56**	**56**	**168**

Table 9: Number of Tests Conducted by Appliance and Dish

Technology and Fuel	Bean stew	Beef stew	Kapenta	Nshima	Porridge	Rape Veg	Rice	Total
Atec Induction	3	3	3	3	3	3	3	**21**
Charcoal Mbaula	3	3	3	3	3	3	3	**21**
Electric Hotplate	3	3	3	3	3	3	3	**21**
EPC	3	3	3	3	3	3	3	**21**
Liquid Ethanol	3	3	3	3	3	3	3	**21**
LPG	3	3	3	3	3	3	3	**21**
Local Induction	3	3	3	3	3	3	3	**21**
Gasifier + pellets	3	3	3	3	3	3	3	**21**
Grand Total	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**168**

4.2 COST OF FUEL PER MEAL COOKED

For each of the ATF-dish combinations all test results were averaged to determine a robust fuel consumption figure. Each dish was prepared to feed a standard family of 5 people and the table below presents fuel consumption for each dish. For example, cooking bean stew with charcoal requires, on average, 1.79 kg of charcoal based on 3 test results. These were then summed across all the dishes for each appliance to determine a "daily[2]" fuel consumption for the set menu. For example, 4.49 kgs of charcoal are required on average to cook all 7 dishes of the daily menu on a traditional mbaula. Fuel consumption was measured in kilograms for LPG, ethanol, pellets, and charcoal. While fuel consumption for all electric appliances is measured in kilowatt hours. For example, 2.97 kilowatt hours of electricity are required to cook all 7 dishes on an EPC, as compared to 7.54 kWhs for the Platinum induction stove.

Table 10: Fuel Consumption by Dish, Meal and Day (kWh/Kgs)

Meal and Dish	Measured in Kgs				Measured in kWhs			
	Ethanol	LPG	Charcoal	Pellet	Atec	Platinum	Hotplate	EPC
Breakfast								
Porridge	0.15	0.08	0.43	0.28	0.56	0.54	0.54	0.47
Lunch								
Nshima	0.17	0.08	0.51	0.38	0.71	0.61	0.76	0.51
Kapenta Stew	0.09	0.03	0.39	0.14	0.23	0.23	0.33	0.28
Rape Veg	0.06	0.04	0.25	0.16	0.25	0.22	0.22	0.19
Dinner								
White Rice	0.10	0.08	0.42	0.17	0.55	0.52	0.50	0.27
Beef Stew	0.24	0.14	0.70	0.87	1.14	2.16	0.95	0.52
Beans	0.58	0.63	1.79	1.46	4.71	4.17	1.74	0.72
Daily	**1.38**	**1.08**	**4.49**	**3.46**	**8.15**	**7.54**	**5.04**	**2.97**

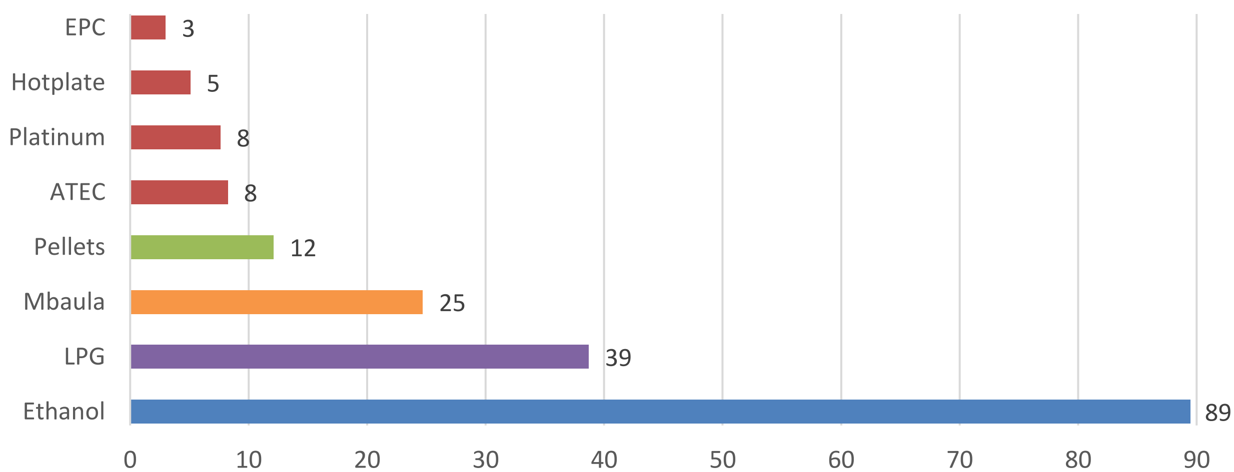
The fuel consumption figures presented above were then converted to a "daily cost of cooking" figure using the fuel price data presented earlier in the report. The graphs in the following sections of this report present the findings based on the **medium fuel prices**, which most typically represent what a household pays. While the tables provide additional detail based on the low and high fuel prices.

Based on the medium fuel prices, the most expensive cooking option was ethanol fuel, costing 89 kwacha per day, this is largely due to the 60% excise duty placed on the fuel. The second most expensive cooking

[2] The term "daily cost to cook" used in this study refers to preparing all 7 dishes, covering the key foods typically eaten for breakfast, lunch, and dinner in Zambia. However, it is unlikely that most households will prepare all these dishes in a day, or every day of the week. Therefore, the "daily cost to cook" is likely an overestimation of the true cost incurred but provides a standardized metric to compare the performance of the different cooking solutions.

fuel is LPG at 39 kwacha per day. This is unsurprising seeing as the price of LPG has doubled in the last 3 years and continues to gradually increase monthly. The next most expensive fuel was charcoal at 25 kwacha per day. Cooking on pellets cost 12 kwacha per day, the two induction cookers cost 8 kwacha per day, while the hotplate costs 5 kwacha, and the EPC 3 kwacha. It is noteworthy that the electric hotplates outperformed the two induction cookers. This result is explored in more detail in section 5.3 of the report where we examine the differing stove specifications, and the behavior of the cooks, as contributing factors leading to this result.

Figure 3: Daily Fuel Cost (ZMW) - Medium Fuel Prices



In terms of time taken to cook the "daily menu", the LPG stove was the quickest (5 hours 19 mins), followed by the ATEC Induction, gasifier, EPC, Platinum Induction, ethanol, charcoal stove, and finally the hotplate (11 hours). The longest dish to cook was Beans which required between 2 hours 8 mins (EPC) and 4 hours 18 mins (hotplate) depending on the appliance.

Table 11: Daily Cost of Cooking Based on Low, Medium and High Fuel Prices

ATF	Meal	Time	Fuel Used (Kg/kWh)	Cost/Meal		
				Low	Medium	High
Charcoal	Breakfast	00:58:40	0.43	1.01	2.37	3.77
	Lunch	02:54:40	1.15	2.71	6.32	10.07
	Dinner	06:51:00	2.91	6.85	16.00	25.50
	Daily	**10:44:20**	**4.49**	**10.57**	**24.7**	**39.34**
LPG	Breakfast	00:20:20	0.08	2.58	2.94	3.54
	Lunch	00:53:20	0.15	4.74	5.40	6.50
	Dinner	04:05:20	0.84	26.63	30.6	36.54
	Daily	**05:19:00**	**1.08**	**33.95**	**38.7**	**46.58**
Electric Hotplate	Breakfast	01:06:20	0.54	0.30	0.55	1.26
	Lunch	02:37:20	1.30	0.73	1.32	3.01
	Dinner	07:27:00	3.20	1.79	3.23	7.38
	Daily	**11:10:40**	**5.04**	**2.82**	**5.1**	**11.65**
	Breakfast	00:31:40	0.56	0.31	0.56	1.29

Induction - ATEC	Lunch	01:02:20	1.19	0.67	1.20	2.75
	Dinner	04:38:00	6.41	3.59	6.47	14.80
	Daily	**06:12:00**	**8.15**	**4.57**	**8.2**	**18.84**
EPC	Breakfast	00:40:20	0.47	0.26	0.47	1.09
	Lunch	01:47:40	0.99	0.55	1.00	2.28
	Dinner	03:56:40	1.51	0.85	1.53	3.49
	Daily	**06:24:40**	**2.97**	**1.66**	**3**	**6.86**
Induction - Platinum	Breakfast	00:36:20	0.54	0.30	0.55	1.26
	Lunch	01:09:00	1.06	0.59	1.07	2.45
	Dinner	04:58:00	5.94	3.33	6.00	13.72
	Total	**06:43:20**	**7.54**	**4.22**	**7.6**	**17.43**
Gasifier / pellets	Breakfast	00:31:00	0.28	0.85	0.99	1.35
	Lunch	01:14:00	0.68	2.03	2.37	3.25
	Dinner	04:29:00	2.50	7.50	8.75	11.99
	Total	**06:14:00**	**3.46**	**10.38**	**12.1**	**16.59**
Ethanol	Breakfast	00:53:00	0.14	9.21	9.21	9.21
	Lunch	01:49:40	0.32	20.91	20.91	20.91
	Dinner	05:51:40	0.91	59.37	59.37	59.37
	Total	**08:34:20**	**1.38**	**89.5**	**89.5**	**89.5**

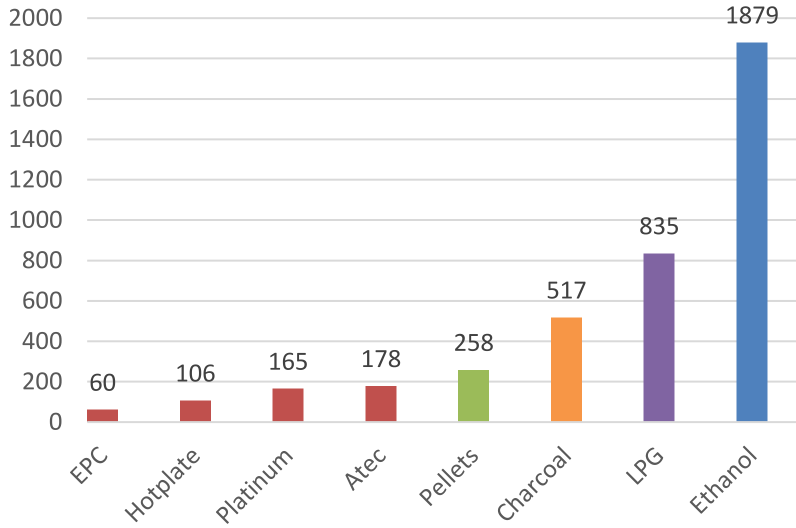
To estimate a **monthly cost** of cooking A2C applied conversion factors to scale the daily cost to a more realistic monthly estimate. These conversion factors recognize that (1) households do not always cook every meal each day and (2) not all meals are cooked fresh, but some are likely to be re-heated and therefore require less fuel (for example, beans). Data used to determine monthly conversion factors was taken from the MECS eCook Zambia Cooking Diaries working paper (2019).

Table 12: Monthly Cost of Cooking Adjustment Factors

Meal	# Days Cooked	% Partially Cooked	% Fuel for Partial Cooking
Breakfast	16	7%	57%
Lunch	19	15%	92%
Dinner	24	27%	79%

It is estimated that breakfasts are prepared 54% of the time (16 days per month), lunches are prepared 62% of the time (19 days) and dinners are prepared 80% of the time (24 days). In addition, not all meals are prepared from scratch, as some are partially cooked (meaning some of the dishes are re-heated and some dishes are cooked from scratch). The MECS report indicates that 7% of breakfasts, 15% of lunches and 27% of dinners are partially cooked. Energy required for partially cooking breakfasts is 57%, lunches 92% and dinners 79% of the amount used to prepare a dish from fresh. It's worth noting that we have used the same partial cooking energy factors for all the fuels. However, in reality, this differs between fuels, for example, re-heating with LPG saves more energy than re-heating with charcoal.

Figure 4: Monthly Fuel Cost (ZMW) - Medium Fuel Prices



Converting the daily cost of cooking figures into monthly estimates does not change their relative performance, or competitiveness, but it does provide a more realistic estimate of monthly fuel use and expenditure. EPCs are highly affordable at 60 ZMW per month. The next most expensive cooking options were the hotplate (ZMW 106), induction cookers (ZMW 165 - 178), and gasifier (ZMW 258). Followed by charcoal (ZMW 517), LPG (ZMW 835) and finally ethanol (ZMW 1879).

Table 13: Monthly Fuel Cost Based on Low, Medium, and High Prices

Technology and Fuel	Meal	Monthly Fuel Used	Cost/Meal		
			Low	Medium	High
Charcoal	Breakfast	6.8	16	37	59
	Lunch	21.2	50	117	186
	Dinner	66.1	156	363	579
		94	**222**	**517**	**824**
LPG	Breakfast	1.3	41	46	56
	Lunch	2.8	87	100	120
	Dinner	19.2	605	689	830
		23	**733**	**835**	**1006**
Electric Hotplate	Breakfast	8.5	5	9	20
	Lunch	24.1	13	24	56
	Dinner	72.6	41	73	168
		105	**59**	**106**	**244**
Induction - ATEC	Breakfast	8.8	5	9	20
	Lunch	22.0	12	22	51
	Dinner	145.5	81	147	336
		184	**98**	**178**	**407**
EPC	Breakfast	7.4	4	7	17
	Lunch	18.2	10	18	42
	Dinner	34.3	19	35	79
		60	**33**	**60**	**138**
Induction - Platinum	Breakfast	8.5	5	9	20
	Lunch	19.6	11	20	45

	Dinner	134.9	76	136	312
		163	**92**	**165**	**377**
Gasifier / pellets	Breakfast	4.4	13	16	21
	Lunch	12.5	38	44	60
	Dinner	56.7	170	199	272
		74	**221**	**258**	**353**
Ethanol	Breakfast	2.2	145	145	145
	Lunch	5.9	386	386	386
	Dinner	20.7	1348	1348	1348
		29	**1879**	**1879**	**1879**

While these adjusted monthly figures provide an estimate which is closer to reality, it's likely that they still overestimate the cost of cooking due to the beans dish which typically accounts for +/- 50% of the cost of cooking and is unlikely to be prepared freshly as frequently as our analysis assumes. This is supported by the MECS finding that beans are re-heated approximately 44% of the time. Making additional adjustments for this would decrease the monthly cost estimate further. But as this would need to be applied equally across all fuels and appliances it does not change the relative cost of cooking between the various options.

4.3 COST OF STOVES PER MEAL COOKED

The previous sections presented the cost of cooking based on fuel expenditure only. However, to fully understand the cost incurred by a household it's important to factor in the initial purchase of the appliance, as well as it's useful lifespan. The table below illustrates the prices paid for the appliances used in the cooking tests and provides an estimate of their useful lifetime in years. This lifetime in years is converted into a lifetime in meals. This was based on 59 meals cooked per month (16 breakfasts, 19 lunches and 24 dinners) making a total of 708 meals per year. The number of meals cooked per year (708) was multiplied by the years of useful operation of the appliance. Finally, the purchase price was divided by the lifetime in meals to arrive at a cost/meal. For example, a traditional mbaula costs ZMW 20 and lasts one year, which is equivalent to 708 meals. Therefore, the cost per meal is ZMW 0.03.

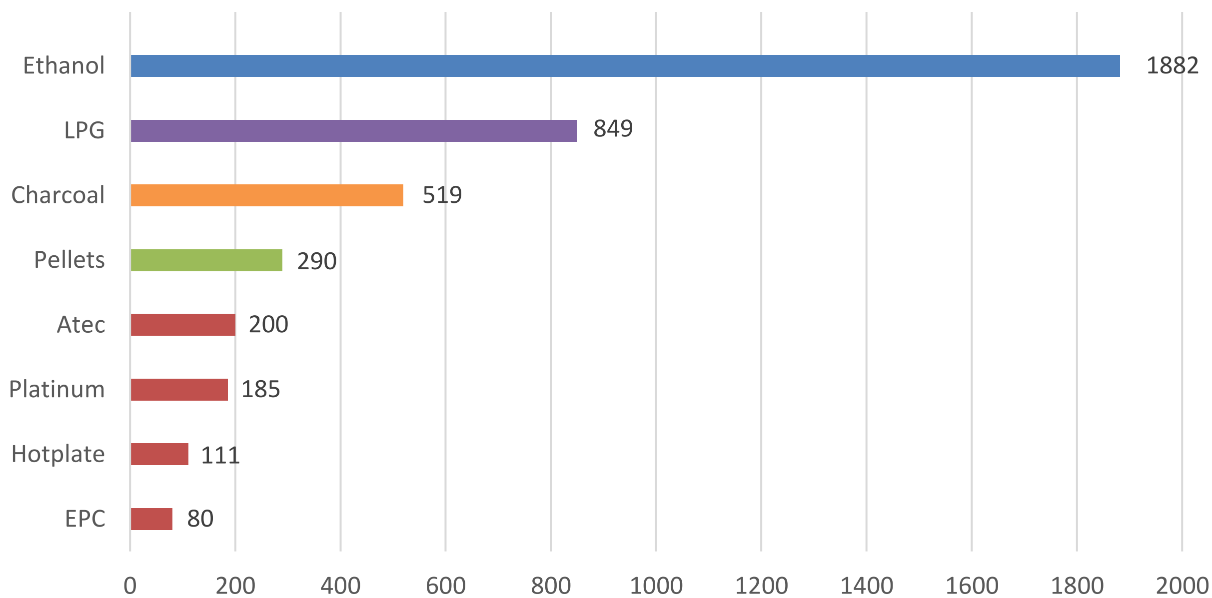
Table 14: Appliance Prices, Lifetimes and Cost Per Meal

ATF	System Price (ZMW)	Lifetime (years)	Lifetime (meals)	Cost/Meal (ZMW)	Cost/Month (ZMW)
Charcoal	20	1	707	0.03	1.7
Ethanol	270	8	5656	0.05	2.8
Electric Hotplate	315	6	4242	0.07	4.4
LPG	980	6	4242	0.23	13.6
EPC	1650	7	4949	0.33	19.6
Induction - Platinum	1750	7	4949	0.35	20.8
Induction - ATEC	2599	10	7070	0.37	21.7
Gasifier/pellets	1900	5	3535	0.54	31.7

4.4 TOTAL COST OF FUELS AND STOVES COMBINED

Combining the fuel expenditure data in section 4.3 with the appliance expenditure data in section 4.4 provides an overall cost of cooking metric for each of the cooking solutions, as presented below. Combining the appliance and fuel costs does not change the overall relative ranking of the cooking solutions.

Figure 5: Monthly Fuel and Appliance Cost Combined - Medium Fuel Prices



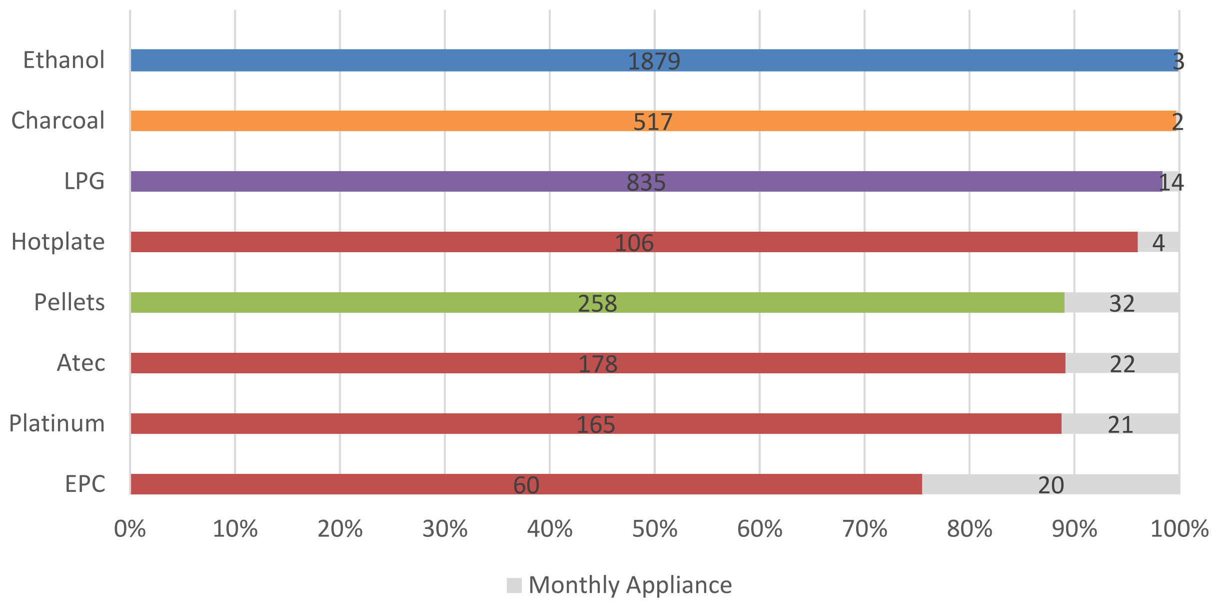
However, due to the high cost of the efficient electrical appliances (EPC and induction cookers), as well as the gasifier stove, and the low cost of the traditional mbaula, the cost of cooking gap narrows between these options. For LPG and ethanol, the gap widens when compared with charcoal, but due to the relatively low cost of these appliances (LPG and ethanol), in comparison with the fuel cost, the difference overall is minor.

Table 15: Combined Cost (Fuel and Appliance) for Low, Medium and High Fuel Prices

Cooking Solution	Cost per Month		
	Low	Medium	High
EPC	ZMW 53	ZMW 80	ZMW 158
Hotplate	ZMW 63	ZMW 111	ZMW 247
Induction – Platinum	ZMW 112	ZMW 185	ZMW 397
Induction – ATEC	ZMW 120	ZMW 200	ZMW429
Gasifier and Pellets	ZMW 253	ZMW 290	ZMW 385
Charcoal	ZMW 223	ZMW 519	ZMW 826
LPG	ZMW 746	ZMW 849	ZMW 1019
Ethanol	ZMW 1882	ZMW 1882	ZMW 1882

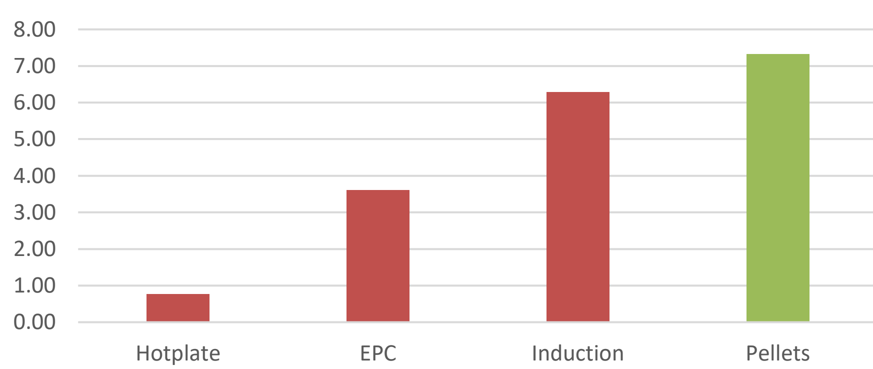
As illustrated in the graph below, the appliance reflects only a fraction of the overall cost of cooking when spread out over its useful lifetime. Typically, the cost of the appliance accounts for between 2% - 20% of the total cooking cost. This reflects the higher prices for the EPC, induction cookers and gasifier stove, as well as the relatively cheap fuel costs for these options. The traditional mbaula is the cheapest of all the appliance options and makes little difference to the total cost of cooking. While the very high prices for ethanol and LPG fuel massively outweigh the relatively modest cost of the appliance.

Figure 6: Monthly Cost of Cooking Build-Up - Stove and Fuel



Based on the average fuel savings of the three electric stoves and pellets compared to charcoal it's also possible to estimate the amount of time it would take an average household to pay off the cost of these stoves, which is summarized in Figure 7. The hotplate is the quickest for a household to pay off, at less than 1 month, with the pellet stove being the longest at just over 7 months. As LPG and ethanol are both more expensive than charcoal these stoves cannot be paid off through the charcoal fuel savings.

Figure 7: Months to Pay Off Stove Cost Based on Fuel Savings Against Charcoal



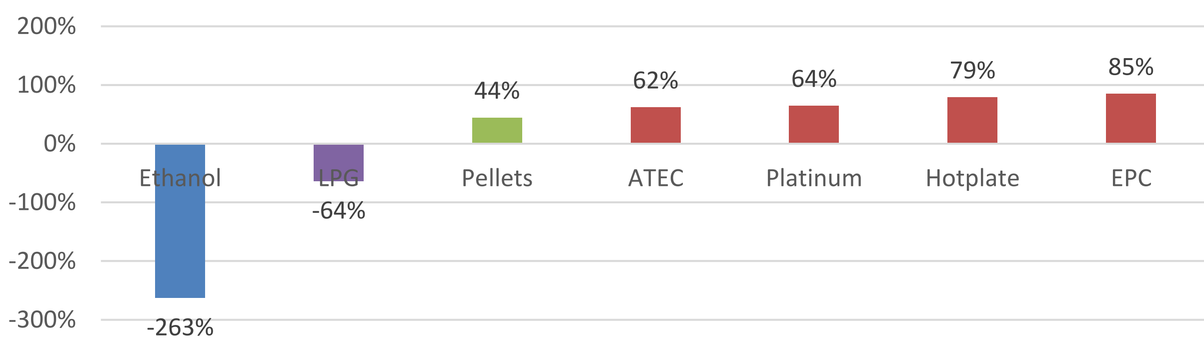
5 DISCUSSION

5.1 COST AND TIME SAVINGS FROM SWITCHING

The results of the CCTs and cost of cooking analysis clearly indicate that some options (LPG and ethanol) are more expensive than charcoal, and some are significantly cheaper (electricity and pellets). The graph below shows the potential savings/losses if a household was to switch from using charcoal on a traditional mbaula. Estimations are based on the medium price point for each fuel, for example, 5.5 ZMW/kg of charcoal and 1.01 ZMW/kWh of electricity.

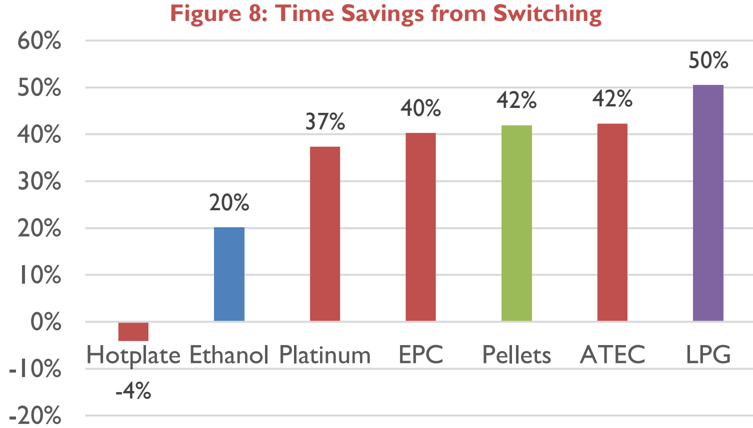
In percentage terms, households could save between 44% (gasifier) and 85% (EPC) of their cooking expenditure by switching. However, if a household was to adopt either LPG or Ethanol, they could spend between 64% and 263% more. These figures include both the cost of the fuel as well as the cost of the appliance (spread over its operational lifetime).

Figure 7: Losses/Savings from Switching - Medium Fuel Prices (including appliance cost)



However, it's important to recognize that the upfront cost of purchasing a new appliance is a significant barrier for most households, even if they will realize longer terms savings. Therefore, consumer financing, through for example PAYGo, could be key to unlocking this barrier and spreading the cost of the appliance over a longer period, as has been done in this study. It's worth noting that while PAYGo technology breaks down larger payments into smaller pieces it does also increase the overall cost due to two main factors (1) the PAYG technology itself adds an additional cost, and (2) companies typically charge interest on PAYGo asset loans.

Figure 8: Time Savings from Switching

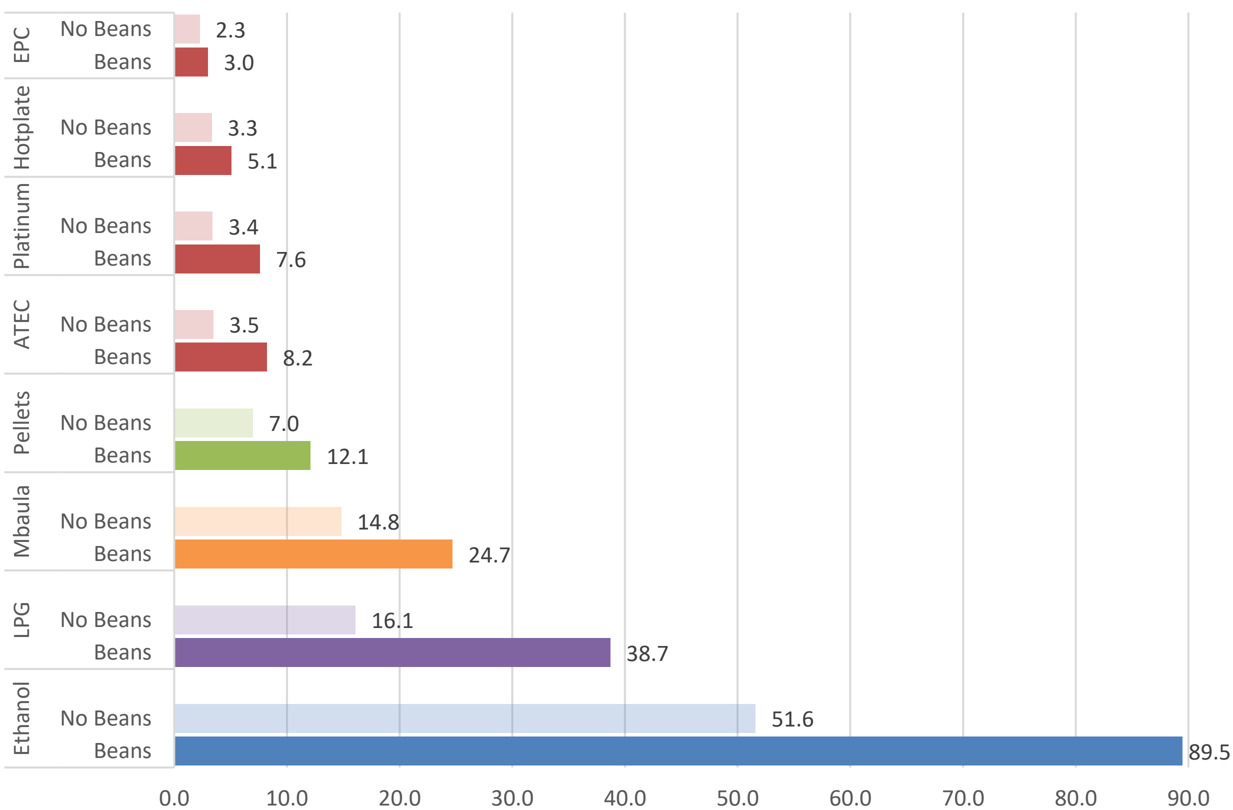


While affordability is a key factor in household decision making, time is also an important consideration for many cooks. Our results show that all the modern alternatives, except for the hotplate, cook more quickly than charcoal. And while LPG is the second most expensive cooking option, it produced the fastest cooking times. Surprisingly, the EPC had very similar results to the induction cookers and pellets when it comes to cooking times. The EPC was the quickest to cook beans, which is the dish that takes the longest amount of time, but the EPC had very similar cook times for the other dishes. And in fact, it took twice as long to cook Nshima on the EPC as compared to the induction cookers, pellets, and LPG. Overall, households could save up to 50% of their time by switching to LPG and approximately 40% of their time by switching to an EPC, induction cooker, or pellets. Time savings are more modest when switching to ethanol (20%), and cooks may even spend slightly longer when cooking on a hotplate.

5.2 THE IMPACT OF BEANS ON THE COST OF COOKING

The cost of cooking, as well as time required, were heavily influenced by the beans dish which requires long cook times and high fuel consumption. Removing the beans dish from the analysis reduces the cost of cooking by between 24% (EPC) and 58% (LPG and Induction) depending on the appliance and fuel. Under our test protocol the beans were not soaked overnight which would reduce the required cook time and could be an important household strategy to decrease the time and cost burden of cooking. Furthermore, as discussed in the following section, using an appropriate power setting when cooking longer dishes will result in lower fuel consumption and a lower cost of cooking, although this comes at the expense of time savings.

Figure 9: Daily Cost With, and Without, Beans - Medium Fuel Prices



Once the beans dish is excluded from the analysis, the electric appliances (EPC, hotplate, Platinum and ATEC) have much more similar cost of cooking results. In particular, the induction cookers (ZMW 3.5) have an almost identical cost to the hotplate (ZMW 3.3). While the gap between the hotplate (ZMW 3.3) and the EPC (2.3) is also reduced. Surprisingly, removing beans from the analysis makes LPG (ZMW 16.1) competitive with charcoal on the traditional Mbaula (ZMW 14.8).

5.3 THE POWER OF COOKING BEHAVIOUR

It is generally accepted that induction cookers, paired with the correct cookware, are more efficient than electric hotplates. So, it is notable that our results indicate that the cost of cooking on an electric hotplate is lower than on both induction cookers, suggesting that the hotplate outperformed the induction appliances.

In trying to make sense of this finding it is important to take into consideration the specifications of the appliances used, as well as the behavior of the cooks. In terms of the specifications, the hotplate was rated at 1000 watts and fitted with a thermostat (representing what is typically found on the market in Zambia), while both the induction cookers were rated at 2000 watts, meaning that the cooks had twice as much power available on the induction cookers as compared to the hotplate. In addition, based on observations, as well as discussions with the cooks, the cooking behavior in Zambia appears to be high power, quick cooking, particularly for those dishes that typically take longer (i.e., beans). Therefore, our findings suggest that a cook will tend to use as much power as they have available to them, regardless of whether the same result could have been achieved with less power. The end result appears to be in-efficient cooking, even on technically more efficient appliances. The term "efficiency" in this context refers to thermal efficiency as measured through the Water Boiling Test and represents how much energy reaches the pot, compared to what is lost to the surroundings.

Table 16: Average Power Consumption by Dish and Appliance

	Beans	Nshima	Rape	Porridge	Beef	Rice	Kapenta	Average
Atec (W)	1,772	1,267	1,172	1,057	1,021	952	873	1,159
Hotplate (W)	405	484	551	510	449	496	525	489
Platinum (W)	1,394	1,021	937	963	1,071	772	748	987

The table above presents the average power used on each dish for the two induction cookers, and the hotplate, as well as an overall average for all seven dishes on each appliance. As can be seen from the overall average, the cooks used more than twice as much power on the induction cookers as compared to the hotplate. While for the beans dish, the power used was three to four times higher on the induction cookers as compared to the hotplate.

Observations of, and interviews with, the cooks revealed that they almost exclusively used the highest power setting on the hotplate, regardless of the dish. And although it was rated at 1000 watts, the thermostat cycled the power on and off to effectively reduce the average power used down to an average of approximately 500 watts for all the dishes. Feedback from the cooks also indicated that they felt the hotplate was not hot enough and they would have liked additional power if possible.

However, as demonstrated by the table below, the higher power use does translate into significant time savings. Based on the total cooking time of all the dishes combined, the cooks achieved a 45% decrease in cooking time on the induction cookers as compared to the hotplate.

Table 17: Cooking Times by Appliance and Dish

	Beans	Nshima	Rape	Porridge	Beef	Rice	Kapenta	Total
Atec	2:38	0:33	0:12	0:31	1:24	0:35	0:16	6:12
Hotplate	4:18	1:35	0:24	1:06	2:07	1:01	0:38	11:10
Platinum	2:59	0:36	0:13	0:36	1:16	0:43	0:19	6:43

It is unclear, based on the results of this study, how these dynamics might change over time, as cooks become more accustomed to the appliances they are using. It's possible that given time, cooks will learn to reduce the power, particularly if they are paying for the fuel (which was not the case in this study). However, it is also possible that cooks value the time saving sufficiently enough to incur the extra cost, particularly if the fuel is cheap (like electricity) and they are still making savings compared to their previous charcoal expenditure.

These findings need further research as they could have important implications for clean cooking companies, policy makers, and practitioners if efficiency gains from clean cooking technologies and fuels are to be realized in the kitchens of typical users. For example, better control of power could be achieved by the inclusion of pre-programmed dish settings on technology enabled appliances, which could help to ensure that appliances are cooking in the most efficient way, much the same way as EPCs function.

5.4 THE ROLE OF HOTPLATES

In recent years the discussion on the role of electric cooking as a tool to achieve universal access to clean cooking has increased. However, the focus has often been on efficient appliances such as EPCs, induction cookers, rice cookers, air fryers etc. This focus on efficient appliances has been largely driven by two factors, affordability, and accessibility. Efficient devices are thought to consume less energy and therefore should be more affordable to run than their in-efficient equivalents. This is particularly important in countries where the cost of electricity is high. In addition, as they consume less energy, they place less stress on national grids, particularly in countries which have an electricity deficit, and this helps to ensure that accessibility of the fuel is reliable.

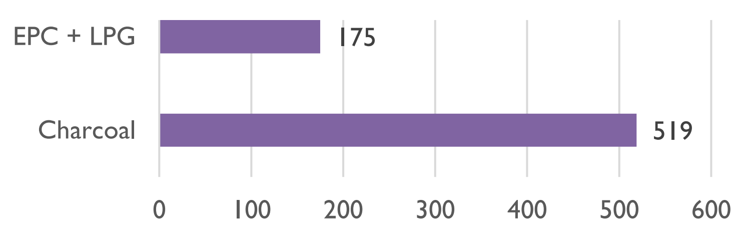
This focus on efficient appliances has pushed the humble electric hotplate to the fringes of the discussion. However, our results show that the hotplate was the second-best performing appliance and outperformed the induction cookers, which are typically considered as efficient electric appliances. As discussed above, this seems in part due to the inherent power limitations of hotplates, which keeps fuel consumption and expenditure down. While the behavior of cooks indicates that they will use as much power as is available, particularly on long cook dishes such as beans, as demonstrated by the induction cooker results. But given that hotplates have a very low upfront cost (ZMW 315) and can cook all the dishes/meals typically eaten in Zambia, should more attention be paid to the role they can play in moving people away from charcoal consumption? Considering the already high level of hotplate ownership in Zambia, and the perception that electric cooking is expensive, a quick win in the battle against charcoal could be effective communication around the true costs of cooking on a hotplate and the savings that can be made compared to charcoal. This should result in increased hotplate use by households that already fuel stack charcoal with a hotplate, reducing the share of charcoal in their stack. In addition, hotplates are relatively simple appliances, and should be able to be repaired, and potentially even assembled or manufactured, locally in Zambia, unlike the EPC and induction stoves, which are considerably more complex.

5.5 AFFORDABLE, ACCESSIBLE, AND ACCEPTABLE CLEAN COOKING STACKS

Urban households in Zambia practice significant fuel and stove stacking based on affordability, accessibility, and acceptability of appliances and fuels. Therefore, a straight switch from charcoal to a single alternative technology and fuel may not meet all their needs. Feedback from the cooks indicated that a combination of an EPC and LPG stove would be their preferred clean cooking stack due to cooking speed (acceptability), ability to cook all common dishes (acceptability), and LPG not being impacted by loadshedding, like the EPC (accessibility).

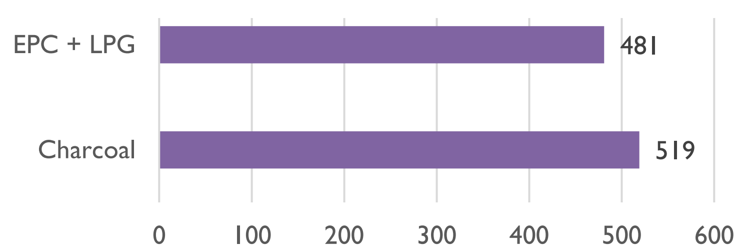
Based on this feedback we have develop two types of clean cooking stack. The **Acceptability Stack** recognizes that some appliances are better than others at cooking certain dishes. While the **Accessibility Stack** recognizes that some fuels are not always available to a user when they require them. <u>All stacks</u> respond to the issue of **affordability** by being at least cost competitive with charcoal, if not significantly cheaper. The analysis presented here is only supposed to be indicative of what is possible, illustrating that households could combine modern cooking solutions into clean fuel stacks and still save money compared to charcoal expenditure.

Figure 10: Acceptability Stack - EPC and LPG - Medium Fuel Prices



Under the **Acceptability stack** for the **EPC and LPG**, the EPC is best suited to cook: porridge (breakfast), white rice, beef stew and bean stew (dinner). While LPG is best suited to cook: Nshima, kapenta stew, and rape vegetables (lunch). These three dishes are less suited to EPCs as they either require specific cooking practices that are hard to achieve on an EPC (e.g., stirring Nshima), or they require cooking styles, such as frying (e.g., kapenta stew), that EPCs were not originally designed to do. Based on the medium fuel prices for each option, the total cost of this cooking stack comes to ZMW 175 a month, compared to ZMW 519 when cooking the same dishes with charcoal. The cost of this stack is simply calculated by adding together the cost of the dishes cooked on an EPC, with the cost of the dishes cooked on the gasifier/pellet stove; the costs include both the fuel and the appliance for a month.

Figure 11: Accessibility Stack - EPC and LPG - Medium Fuel Prices

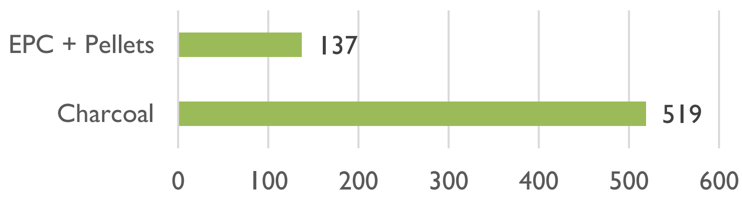


The **Accessibility stack** for EPC and LPG recognizes that some fuels are not always available to a user when they require them. Zambia experiences seasonal electricity "loadshedding" of up to 12 hours a day, making electric appliances such as EPCs unreliable. While refilling, or exchanging, LPG cylinders can often be challenging, with some households having to travel up to 5km. Under this stack, cooking is split 50:50 between the two options. Based on the medium fuel prices for each option, the total cost of this cooking stack comes to ZMW 481 a month, compared to ZMW 519 when cooking the same dishes on charcoal. The cost of this stack was simply calculated by adding together half the cost of the dishes cooked on an EPC, with half the cost of the dishes cooked on LPG; the costs include both the fuel and the appliance for a month.

However, as demonstrated in this study, LPG is one of the most expensive cooking solutions (affordability). A cheaper alternative, which delivers an almost identical service, is the pellet gasifier stove. Therefore, we have modelled two potentially optimal clean cooking stacks, based on a combination of an

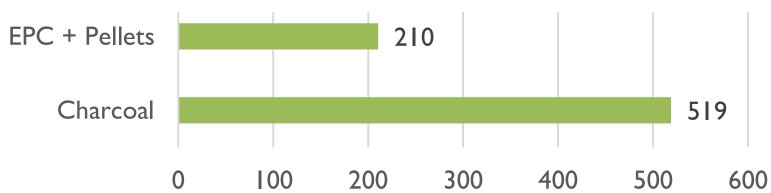
EPC and a pellet gasifier stove. Both appliances are cheaper than charcoal, however, each has weaknesses related to accessibility and/or acceptability.

Figure 12: Acceptability Stack - EPC and Gasifier - Medium Fuel



Under the **Acceptability stack** for the **EPC and Gasifier**, the EPC is best suited to cook: porridge (breakfast), white rice, beef stew and bean stew (dinner). While the Gasifier is best suited to cook: Nshima, kapenta stew, and rape vegetables (lunch). These three dishes are less suited to EPCs as they either require specific cooking practices that are hard to achieve on an EPC (stirring Nshima), or they require cooking styles, such as frying (kapenta stew), that EPCs were not originally designed to do. Based on the medium fuel prices for each option, the total cost of this cooking stack comes to ZMW 137 a month, compared to ZMW 519 when cooking the same dishes with charcoal. The cost of this stack as simply calculated by adding together the cost of the dishes cooked on an EPC, with the cost of the dishes cooked on the gasifier/pellet stove; the costs include both the fuel and the appliance.

Figure 13: Accessibility Stack - EPC and Gasifier - Medium Fuel Prices



The **Accessibility stack** for the **EPC and Gasifier** recognizes that some fuels are not always available to a user when they require them. Zambia experiences seasonal electricity "loadshedding" of up to 12 hours a day, making electric appliances such as EPCs unreliable. While pellet availability is also limited with only one commercial supplier operating in Zambia. Under this stack, cooking is split 50:50 between the two options. Based on the medium fuel prices for each option, the total cost of this cooking stack comes to ZMW 210 a month, compared to ZMW 519 when cooking the same dishes on charcoal. The cost of this stack was simply calculated by adding together half the cost of the dishes cooked on an EPC, with half the cost of the dishes cooked on the gasifier/pellet stove; the costs include both the fuel and the appliance.

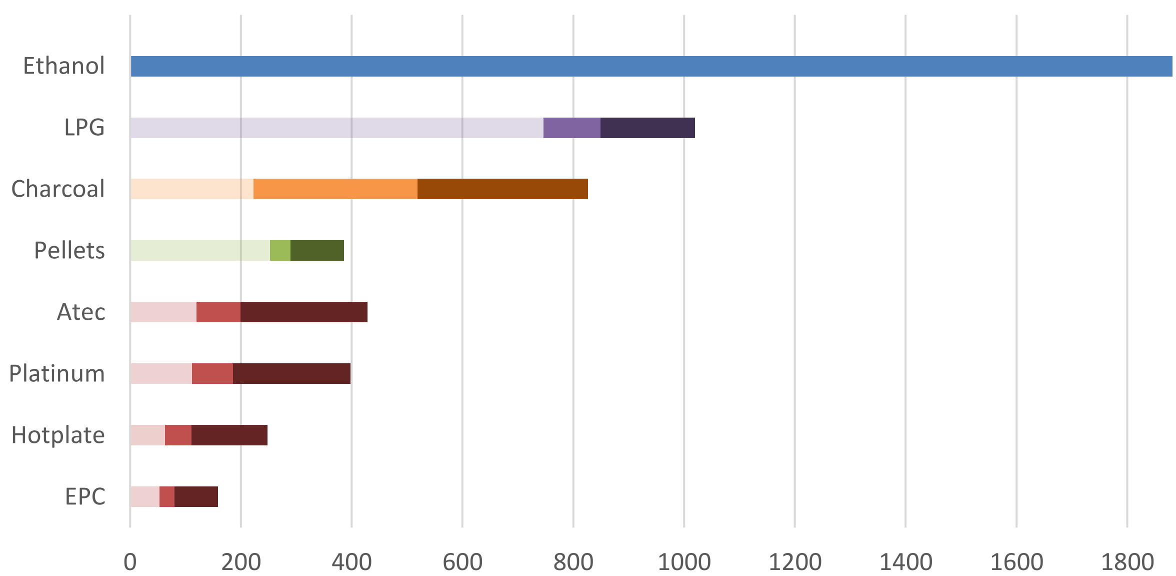
5.6 IMPACT OF FUEL PRICES ON COST OF COOKING

The main contributor to the cost of cooking comes from the ongoing fuel costs, as opposed to the cost of the appliance. Therefore, fluctuations, or variations, in the price of the fuels can have an impact on the competitiveness of one cooking option over another. In this study A2C has used three pricing levels for LPG, charcoal, pellets, and electricity, as explained earlier and summarized in table 18 below. Due to the nascent state of the sector, only a single ethanol fuel price has been used, and regardless of the other fuel price levels, it remains the most expensive cooking option.

Table 18. Fuel Price Scenarios: Low, Medium, High			
Fuel	Low Price	**Medium Price**	**High Price**
LPG (ZMW/Kg)	33.4	36.4	42.9
Charcoal (ZMW/Kg)	2.4	5.5	8.8
Pellets (ZMW/Kg)	3	3.5	4.8
Electricity (ZMW/kWh)	0.56	1.01	2.31
Ethanol (ZMW/Liter)	65 ZMW/liter		

LPGs performance against charcoal depends greatly on the price paid per kilogram of charcoal. For the lowest charcoal price (2.4 ZMW/kg) LPG is a significantly more expensive cooking option. At the medium charcoal price (5.5 ZMW/kg) LPG remains a more expensive cooking fuel. However, at the highest charcoal price (8.8 ZMW/kg) LPG becomes competitive with charcoal. Typically, lower charcoal prices are associated with purchasing larger bag sizes. However larger bags require a higher purchasing power. Conversely, higher charcoal prices are typically associated with smaller bag sizes. These smaller bag sizes are usually purchased by poorer households, with unpredictable incomes, who lack enough disposable income to purchase the largest bag sizes. Therefore, the poorest charcoal users are paying the most for their fuel and could feasibly switch to PAYGo LPG if it can be offered at a competitive price point.

Figure 14: Monthly Fuel and Appliance Cost - Low, Medium and High Fuel Prices



Cooking with pellets is cheaper than charcoal when using the medium and high charcoal prices. However, using the low charcoal price makes cooking with pellets slightly more expensive than charcoal. This strongly suggests that pellets should be targeted at low to medium income households who generally pay more for their charcoal. At the lowest electricity tariff (0.56 kWh) all the electrical appliances are the cheapest cooking option. At the highest tariff (2.31 ZMW/kg) the induction cookers become more expensive than pellets but remain cheaper than charcoal at the medium and high charcoal prices. Even at the highest tariff the EPC remains the cheapest cooking option.

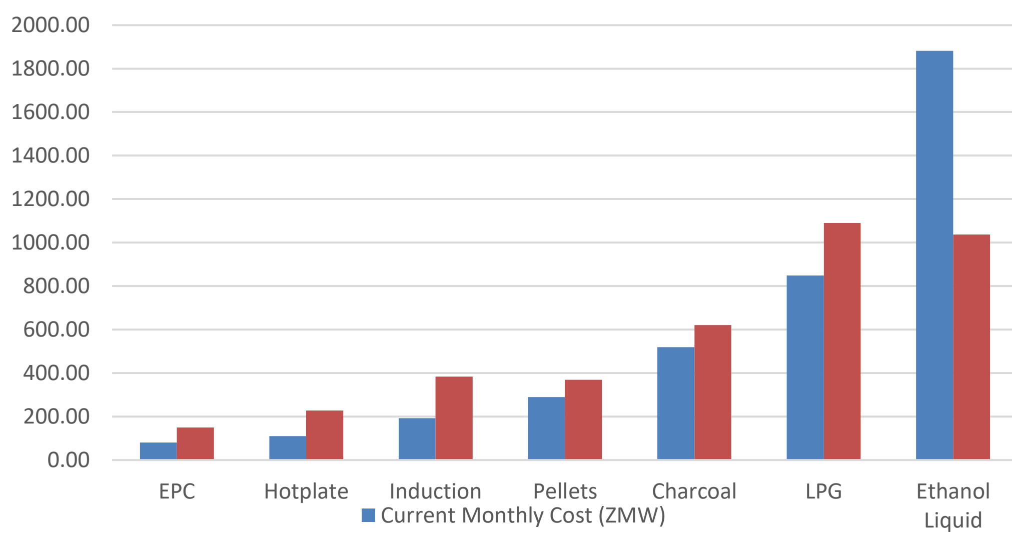
5.7 ESTIMATES OF FUTURE PRICE INCREASES AND THEIR IMPACT

In addition to understanding the current relative prices of cooking appliances and fuels in Zambia, it is also useful to look at how the fuel and stove costs are likely to change by the end of the A2C project, in December 2025, and Figure 12 outlines the current and projected monthly fuel and appliance costs. The projected stove costs were based on the average inflation price, while the projected fuel costs were based on various assumptions, including ZESCOs planned 145% electricity price increases split over 5 years, the recent past and projected future price trends for LPG and charcoal, the planned future price rises of pellets and the price of liquid ethanol if the current tax exemption waivers being lobbied for are successfully implemented, as summarized in Table 19.

Table 19: Current and Future Fuel Prices		
Fuel	**Current Prices (ZMW)**	**December 2025 Prices (ZMW)**
Electricity EPC	1.01	2.11
Electricity Hotplate	1.01	2.11
Electricity Induction	1.01	2.11
Pellets	3.50	4.50
Charcoal	5.50	6.58
LPG	36.40	46.50
Ethanol Liquid	65.00	35.91

Based on this it is likely that cooking with EPC and hotplate electric will remain the cheapest cooking options in Zambia, although pellets may become cheaper to cook with than induction stoves if pellet prices don't rise higher than our projected increase. LPG is likely to continue to be more expensive than charcoal. However, cooking with ethanol could become cheaper than cooking with LPG if the ethanol fuel tax exemptions are implemented, and the price of ethanol could further decrease if more producers of ethanol fuel start operating in the market following the tax exemption.

Figure 15: Current and Projected Monthly Fuel and Appliance Cost



6. KEY TAKEAWAYS

Key Takeaways

- Fuel prices can have a significant impact on the relative performance of the cooking solutions. Charcoal and electricity have the widest price ranges of all the fuels. Both increase roughly fourfold between the cheapest and most expensive options. While the price variations for LPG, ethanol and pellets are more modest.
- The cost of the appliance, when spread across its operational lifetime, is a minor contributor to the overall cost of cooking (results summarized here include both the fuel and the stove). However, without consumer finance, the upfront cost of the appliance is likely to remain a barrier.
- At the low and medium tariffs electricity is currently the most cost-effective fuel, and cooking with an EPC is the most cost-effective appliance. Even at the highest tariff an EPC is the cheapest cooking option.
- Hotplates were the second cheapest cooking option, suggesting more focus should be placed on the role they can play in reducing charcoal consumption in grid-connected households.
- Using a gasifier stove with pellets is cheaper than charcoal at the medium and high charcoal price points but using the lowest charcoal price makes cooking on charcoal slightly cheaper than pellets.
- Liquid fuels (ethanol and LPG) are the most expensive cooking fuels. However, compared with the highest charcoal price, LPG can be cost competitive. This suggests that PAYGo LPG, targeted at lower income charcoal consumers, could be an attractive offer.
- Cooking bean stew has a major impact on the cost of cooking. Removing beans from the analysis makes LPG cost competitive with charcoal at the medium fuel price points. Removing beans also makes the induction cookers perform the same as the hotplate.
- Performance of the appliances, with the exception of EPCs, seems to depend heavily on the behavior of the cooks. Cooks tend to use as much power as is available to them, which impacts fuel consumption and ultimately the cost of cooking. Including pre-programmed dish settings could be an important strategy to ensure efficiency gains are realized in households.
- The most effective clean cooking stack based on affordability, accessibility, and acceptability is the EPC with the Gasifier stove. This stack allows households to cook all dishes (acceptability) at a lower cost than charcoal (affordability) and ensures they are not impacted if there are shortages with either of the fuels (accessibility)
- Projections of future price increases up to December 2025 suggest that electricity and pellets will remain cheaper than cooking on charcoal. LPG will remain more expensive than charcoal, while securing excise duty waivers on ethanol could make it less expensive than LPG.